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Technical Note

Consequences of the Recently Modification of Iran Seismic Design Code (No. 2800) (Due to $A*B$ Form) and Proposing Forward Directivity Effects Coefficients (N_a and N_v)

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ABSTRACT: This article intends to discuss and assess the weaknesses of Iran seismic design code (No. 2800, 4th version) including spectral ordinates at the constant maximum acceleration and velocity ranges, starting point at response spectra. The dependency of corner period (T_s) on the strength of strong motion rather than the spectral ordinates at constant maximum acceleration as it is in the existing forms is discussed. A simple methodology for predicting the period dependent forward directivity effects parameter, $N(T)$ is proposed. The real spectral ordinates data at 120 near source sites on the four types of soil types from the two cities in the United State are used to develop the proposed forward directivity factor $N(T)$. The average values of the obtained design response spectra are compared with those of the 2800's third and fourth versions and the differences are assessed. It is concluded that modifying the currently used design response spectra seems to be inevitable due. Further, the parameter (S) in the existing spectral shape form $(S+1)B_1(T)$ seems to be the cause of ambiguity to the users and needs to be changed in current status. Finally, four new forms of design response spectra are proposed meanwhile a conscious solution for the forward directivity effects parameter representative $N(T)$ is recommended.

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1- Introduction

Ground motions close to the active faults are principally influenced by the rupture mechanism, wave propagation alignment toward the site and ground motion permanent displacement. Strong motion pulses at near fault site, distances within a radius of about 20 km away from the active fault, in addition to their high kinematic energy contain specific characteristics quite different from those at far field. One of the properties is the forward directivity phenomena which may cause huge building damages and human life loss. Such phenomena often appear as velocity pulses at the beginning of velocity time-history having large amplitude associated with long period. Samples of internal events are the 2003 Bam M6.3 [1], 2005 Zarand M6.2 [2] and external events of 199 M7.8 Ezmit, Turkey [2], 1999 M7.6 Chi-Ch- Taiwan [3], 1994 M6.4 Northrich [4], 1995 M6.9 Kobe, Japan [5], and 1992 M7.3 Landers USA [6]. Many research works have been carried out during the last decade to rationally understand the qualitative and quantitative factors influencing strong motion happening. In brief, the most effective factors of producing directivity effects are: ground motion magnitude (M), fault rupture potential to produce forward directivity and the orientation of site relative to wave propagation direction.

2- Challenges on the existing Iran Seismic Code (Standard No. 2800)

The recent version of Iran seismic code design response spectra is the modification forms of version three which had been inspired from those of 1994 USB. The response spectra are changed to reflect a $1/T$ falloff in the period range of maximum constant velocity rather than the previous form as; $1/T^{2/3}$ and eliminating the 1.2 factor. The major challenges in the currently used response spectra are summarized as follows:

• Dependency of corner periods (T_s) on the earthquake intensity

It is quite clear that the spectral ordinate corresponding to "the corner period T_s" which is defined as: the intersection of the two spectral ordinate ranges, maximum acceleration and maximum velocity, is directly dependent on the earthquake strength rather than those only at constant maximum acceleration. Fig. 2 shows the response spectra of three strong motions having different magnitudes. Strong motion information is listed in Table 1. As seen the strong motions are associated with magnitudes of 5.6 to 7.6 Richter. The difference of spectral ordinates at corner periods (T_s) are quite visible. The independency of strong motion spectral ordinate values at these two ranges can also be shown in the mathematic Fourier series form of ground motion time-history (see Eq. (1)).

It is quite clear that the spectral value at T_s depends on those of both ranges: maximum acceleration and velocity spectral ordinates, in other words, strong motion intensity. The influence of different levels of earthquakes intensity on the spectral amplitude at T_s is quantitatively demonstrated by comparing the seismic design response spectra presented by

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ASCE (ASCE-7-2005). The corner period in ASCE is defined as: T_s=[(F_v×S_1(T=1))/(F_a×S_s(T=0))], where, F_a and F_v are two amplification factors (site effect) representing the site soil type, S_1(T=1) and S_s(T=0.2) are spectral ordinates at one and 0.2 seconds measured at bed rock [ASCE-7-2005]. The corner periods for different levels of earthquake corresponding to the site soil type E are calculated and compared. Table 3 reflects the corner periods obtained from different ground motion strengths at soil type E. As seen, different S_s and S_1 levels show different corner periods reflecting that spectral ordinate at T_s is influenced by those of both sides (i.e., of earthquake strength) which very differently as earthquake gets larger intensity.

Therefore, pre-specifying spectral ordinate value at T_s (from constant maximum acceleration) and defining spectral ordinates at constant maximum velocity range as proportional to 1/T, as is in the Iran Seismic Design Code (Standard No. 2800), means neglecting the influence of strong motion at periods longer than T_s. This is principally in contrast to the real observed response spectral data and is as the consequence of separating response spectra in two independent parameters, A and B(T).

This problem is arisen from the general form of Iran seismic code response spectra in the form of two separated parameters: basic design acceleration (A) and spectral shape parameter B(T).

• The independency of spectral response from site-source distances

In 2800 code, the response spectra are not influenced by the site-source distance. This issue is of significant importance if far and near source sites particularly those at the maximum constant acceleration (AB in Fig. 1). The consequences of this shortcoming are comprehensively discussed at [7].

• Spectral ordinate at starting point of response spectra [A*B(T=0)]

Spectral ordinate at starting point of any response spectrum (or design response spectra) reflects the PGA of corresponding strong motion (or probabilistic form of PGA). Regarding that the 2800's response spectra from the first to the third versions have been modified, it implicitly reflects that the modifications have not be done on the basis of recorded data set rather are made as a justification process. Therefore, the spectral ordinates of 2800's code at T_0 for the four types of site soil conditions, i.e., A*B(T=0), can't be represented by the existing values. In other words, their real values are missed and needs to be reviewed.

• Inconsistency of the forward directivity factor, N(T), with those of New Zealand (NZS-1170.5).

This period dependent parameter is presented to model the ground motion forward directivity effect at near source sites and is claimed to be majorly inspired from that at NZS-1170.5. However, it is shown that the existing N(T) factor is strongly inconsistent with those of the New Zealand which is comprehensively discussed in [8].

This article intends to qualitatively present a simple method to implement the forward directivity effects at near source site by means of the observed data from the two cities in USA, San Francisco and Los Angeles. Notably, the existing Iran standard seismic code response spectra in the forms of two separated parameters and the maximum value of N(T) factor (1.7) are accepted in this study in spite of their big problems.

• Finally, confusion arisen from the use of (S) parameter in spectral shape formulation definition:

B=(s+1)(T_s/T).

The dimensionless parameter (S) in this relationship doesn't represent any physical meaning or factor in spectral shape rather it is used for simplicity purpose. Actually, this form of presenting a factor of spectral shape factor B(T) is expected to somehow reflect a physical earthquake phenomenon while it only makes some sort of ambiguity to the user in the cost of simplicity.

3- Proposed approach

This article intends to propose a simple approach to implement the forward directivity effects at near source sites to the existing seismic design response spectra in the Iran 2800 Code. The approach is derived on the basis of extracted data at near fault sites (less than 20 m) in the two well-known cities of the United State; Los Angeles and San Francisco in California. These two cities are chosen for the reason of seismicity similarity to Iran's cities such as Tehran. For this purpose, fifteen sites in each city are selected determining the site's design response spectra (at the periods of 0.2 and one second). The obtained spectral amplitudes at the two ranges of periods; constant maximum acceleration and constant maximum velocity, are averaged. Two sets of data for each site soil condition, are extracted from the information of these two period ranges by dividing the averaged values to those of the Iran response spectra. This process ended up with two sets of data where the forward directivity effects are included in the constant maximum velocity data. Finally, two lines are fitted among the obtained data ending up with a coefficient for the constant maximum acceleration ranges denoted by N_a and a period dependent parameter for the constant velocity ranges denoted by N_v(T). Tables 4 and 5 shows the values of these two factors for four site soil conditions. In order to realize the upper bound of forward directivity effects existing in the data, the Los Angeles response spectra (in averaged value) are compared with those of the third version of 2800'response spectra. The reason of such comparison is that it is believed that the third version response spectra are associated with very large directivity effects. Figs. 5 show such comparison. As are show, the proposed response spectra are partly associated with larger or smaller values. It somehow tells us that forward directivity effects should be predicted on the basis of real data. Figs. 6 display the obtained response spectra, the proposed forms, and those of the third and fourth response spectra in the both ranges; constant maximum acceleration and constant maximum velocity.

4- Conclusion

This article intends to highlight, discuss and assess the shortcomings of the existing Iran Seismic Design Code response spectra (standard No.4) and propose a simple methodology for developing a period dependent forward directivity effects parameter N(T). Five questionable points of the currently used 2800's response spectra are discussed and their roots of shortcomings including the constant maximum acceleration and velocity are mentioned. A new simple approach to implement the forward directivity effects in the constant maximum velocity of the existing response spectra are proposed. The data used to develop the proposed period dependent parameters (N_a and N_v) are obtained from those of the two cities in the United State. It is concluded that the existing design response spectra for the four site soil types need to be modified in the constant maximum acceleration and the maximum constant velocity. Moreover, the existing forward direct effect parameter $N(T)$ needs to be reviewed in a manner that cover the real near source data. Additionally, the existing parameter (S) in the formulation of spectral shape B(T) should be omitted by adding its role to a new the seismicity parameter. Meanwhile, the proposed real data-based design response spectra, for four site soil types, may be used while a regional comprehensive study seems to be highly necessary to be performed particularly in the highly populated cities such as Tehran.

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